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INDEXING THE HUMAN-NATURE RELATIONSHIP IN CITIES

Guoping Huang

Department of Urban and Environmental Planning, University of Virginia, USA

HIGHLIGHTS

- City Index is a popular instrument to evaluate a city's performance in different aspects.
- The evolution of City Index reveals the shift of focus from the economy to ecology.
- The Biophilic City Index is designed to evaluate the human-nature relationship in cities.
- The Biophilic City Index assesses natural services, eco-systems, and human interactions with nature.

ABSTRACT

Since the globalization of the world's economy, there has been a surge in studies ranking international cities by quantitative indices. This paper examines various city indices and identifies the transition from an economy-centric approach towards a sustainability-oriented approach through the lens of those contributing variables used in different indices. The paper then introduces a new Biophilic City Index as a way to examine the human-nature relationship, i.e. biophilia, in cities. It is structured at three different levels: from nature service to ecological integrity to human-nature interaction. This index enriches existing city indices and encourages city planners and policy-makers to make cities more biophilic.

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ghuang@virginia.edu
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1. THE EVOLUTION OF CITY RANKING AND CITY INDICES

The globalized economy highlights the importance of cities in the global trade network (Sassen, 1991). It not only sets the stage for cities to compete globally, but also fuels a new field of urban study: city ranking by constructed indices. Today, an ever-expanding range of governmental institutions, private consultancies, research foundations, and media outlets are now producing or using these city indices as a reference. International companies who are engaged in globalized economy rely on these indices to compare the economic vitality of different cities to make their investment decisions. They also look for standard and quality of living information to manage human resources internationally. City leaders and planners make comparisons between peer cities as well to inform strategic decisions or to address shared imperatives and challenges(Taylor, 2011). Economic, social and environmental aspects of cities are all given in-depth coverage by various city ranking studies.
In synthesis, these indices provide urban researchers with a comprehensive picture of major urban issues that many industries, agencies, and institutions care about. However, in each city index exist dozens of contributing indicators. The selection of these indicators in different indices and different times could reveal a more in-depth trend of preference in city ranking. Therefore, this study investigates the evolution of the indicators that contribute to a collection of more than 20 of the most influential city indices in recent decades. The criteria for selecting influential city indices are: 1) international media coverage of the release of this city index; 2) citation of the city index in international medias outside of its original country, or a Wikipedia entry for the city index, or reference by scholarly researches and 3) a white paper or report available with detailed listing of contributing indicators to the index. Table 1 shows the city indices used in this study.

Table 1: International City Indices

Indices	Starting Year
International Living Quality of Life Index	1984
European City Monitor	1990
Globalization and World Cities Research Network (GaWC)'s Inventory of World Cities	1998
Mercer's Quality of Living Survey	2001
Anholt-GfK Roper City Brands Index	2006
Global Financial Centers Index	2007
Cities of Opportunity	2007
Global Urban Competitiveness Index	2007
Monocle Quality of Life Index	2007
Global Power City Index	2008
A.T. Kearney's Global Cities Index	2008
Euromonitor International's Top City Destination	2009
2008 Legatum Prosperity Index	2008
Gallup-Healthways Well-Being Index	2008
Europe, Latin America, Asian, US & Canada, African Green City Indicies	2009
8 Dimensions of a Healing City	2010
International Ecocities Framework and Standards	2010
Mercer Eco City Index	2010
Soul of the Community	2010
Urban world: Mapping the economic power of cities	2011
EIU-Siemens Green City Index series	2012
Global Cities Survey: The wealth report	2013
EIU Global Livability Report	2013
European Smart Cities	2013

The approach to study the evolution of these indices is to chronologically document the emergence of these indices as well as their associated contributing factors and indicators. For instance, the Global Power City Index, developed by the Institute for Urban Strategies with leading professors in the field of urban studies, is based on six “functions” with 69 individual indicators (Institute for Urban Strategies, 2011). All the indicators, which are mostly numeric, are further categorized into three general groups based on the following categories of urban issues: 1) economy, which covers aspects of economic vitality, 2) social and public service, which covers a variety of social services and public services, and finally 3) environment, which covers everything about the physical and natural environments. In the Global Power City Index example, there are 22 indicators in the economy group, 37 in the social and public service group, and 10 in the environment group. The percentage of each category across all the indices by the year of inception is calculated and presented in Figure 1. The result reveals the evolution of city ranking indices through three eras:

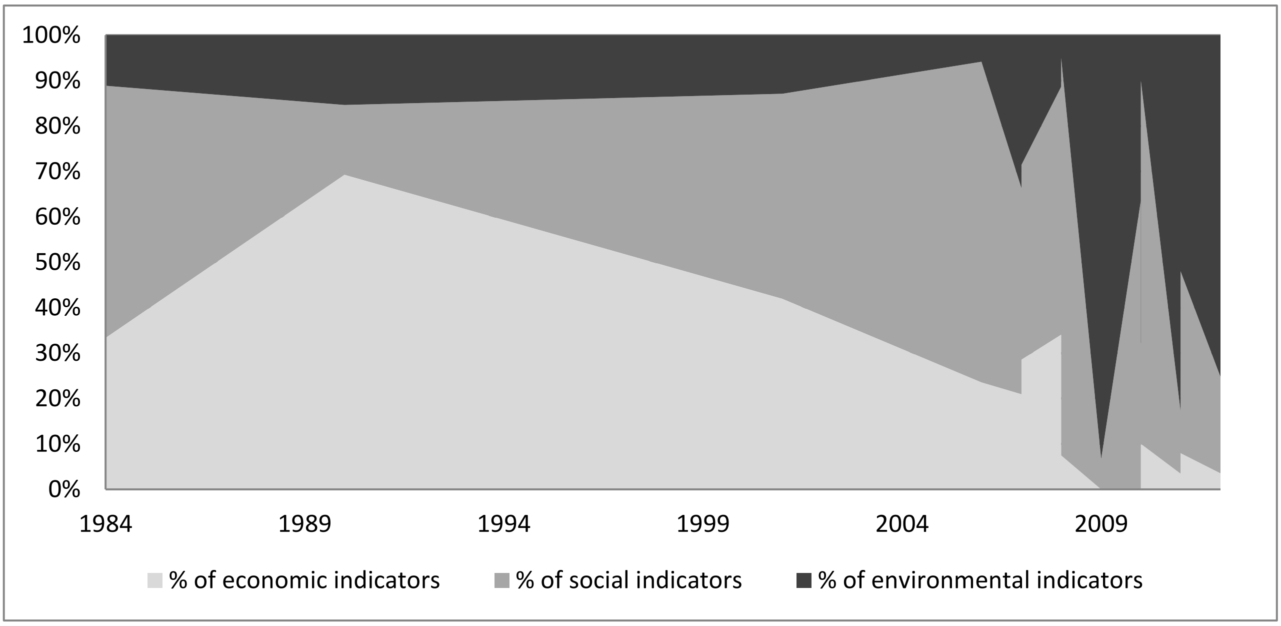

Figure 1: Change of shares of indicators in city indices over time

- The global economy era:

The global city research started with the research about the role of cities in the global financial market. Scholars identified the process of “world city formation” (Friedmann, 1985) and started to study cities as “international financial centers” (Cohen, Dear, & Scott, 1981). The globalized economy started to redistribute resource and production capacities globally, mainly through cities. To help large international companies find an ideal target city or country for investment, the first generation of city ranking studies was produced mainly for large firms to evaluate the economic status and growth potential of different cities and make decisions (Taylor, 2011). The most exemplary index in this era is probably the Inventory of World Cities by GaWC (Beaverstock, Smith, and Taylor 1999) that gives the popularity of the term “alpha city” in the business world and academia.

- The livability era:

As globalization progresses, large international firms start to harvest not only labor and natural resources globally, but also capital and brains. As a result, they deploy and manage employees internationally. Meanwhile, the standardization and globalization of basic social and health services gave many talented individuals in large companies the freedom to choose where to work and live.

Measuring quality of life, or livability of cities, is the immediate response to the demand of the hyper-mobile world that emerged in the 1990s and 2000s. Various products of livability indices, such as Mercer's Quality of Living Index, were made to aid large companies in crafting compensation packages for expatriate employees (Taylor, 2011) and make decisions on human resource management. On the local scale, the quest for a higher quality of urban life remains the overarching goal for many city leaders as it unites the needs of citizens, businesses, investors, and visitors in a city. Important indicators like local amenities, connectivity, high-quality public services, along with later additions of security and entrepreneurial freedom, have been found in comprehensive city indices.

- The eco era:

Cities are playing increasingly important roles in climate change and sustainability. The terms "sustainable city" and "eco-city" emerged in the 1980s and turned the focus of sustainability to the largest man-made entity: the city (Register, 1987). In 1984, UNESCO identified five basic elements of eco-cities: environmental protection strategies, ecological infrastructure, improvement of living standards, cultural and historic conservation, and natural assets within city boundaries (Brookfield, 1984). Similar concepts followed, such as ecopolis, carbon-neutral city, green city, and the self-sufficient city (Beatley, 1999; Lehmann, 2010; Register, 1987). The general purpose behind these new concepts was to integrate ecological concerns and the carrying capacity into the development of a city. Measuring how cities perform ecologically has given birth to many new city rankings and indices. Although some indicators related to the physical environment had already been used in many livability indices, it is only in this era that sustainability has emerged as a prominent feature of some comprehensive city indices. For example, Mercer, which had long been famous for its livability index, launched an Eco-City Index in 2010 to focus solely on urban sustainability issues.

2. BIOPHILIC CITIES AND THE BIOPHILIC CITY INDEX

2.1 Biophilia and Biophilic Cities

The expansion of sustainability-oriented indicators in city indices demonstrates growing concerns over the quality of the urban living environment and the sustainability of our eco-system. This trend echoes many other researches and thoughts in different disciplines. The theories and methods used in traditional ecology are now being applied to socio-economic dimensions to study urban eco-systems (Pickett et al., 2008). Landscape Urbanism argues that the landscape should be the organizing element of the city, not the buildings, as traditionally thought (Steiner, 2011). A similar perspective, Ecological Urbanism, calls for designers to be inspired by ecology to define new values and aesthetics of urban development (Mostafavi & Doherty, 2010). Myrmecologist and conservationist E.O. Wilson proposed the concept of biophilia, "the innately emotional affiliation of human beings to other living organisms." (Wilson, 1986). Recently in 2013, Professor Beatley at the University of Virginia launched the Biophilic Cities Network project to promote the awareness of biophilia in the cities. In Beatley's discussion of the concept of "biophilic cities," the connection between urban residents and nature ranges across different scales, from the intimate immersion in the natural environment to the visual and acoustic connection one has with nature to the responsibility of fostering the global biodiversity eco-system (Beatley, 2010). To give city managers, planners, and researchers a way to measure such biophilia, a Biophilic City Index, or human-nature relationship index, has been developed to extend and complement the existing city indices.

2.2 *Biophilic City Index*

The Biophilic City Index is structured as a three-level hierarchy. On the fundamental level exist the basic natural services we need from nature: air to breathe, water to drink, and productive land to feed the populace. The second level is the ecological level, supporting a healthy ecological system with fauna and flora (Ignatieva & Ahrné, 2013). The top level is the biophilic level that facilitates interaction between human and nature. This structural model also demonstrates the hierarchy of priorities. A healthy physical environment is the foundation of any ecosystem. A healthy ecological system needs to support the prosperity of vegetation and wildlife species so that urban residents can enjoy. In the following section, Portland, one of the partner cities in the ever-expanding Biophilic Cities Network, is used as an example to illustrate how the major indicators could be quantitatively assessed.
Due to the various sizes and densities of cities, it is important to delineate a study area to make the statistics on each city comparable. First, each city's built area is identified with supervised classification tools in remote sensing. Then a minimum bounding rectangle that encompasses twice of the built area beyond the built city is delineated as the study area.

Table 2: Key indicators of Biophilic City Index

Basic services	**Ecological system**	**Human-nature interaction**
Air quality	Vegetation Index	Access to small or pocket parks
Water quality	Percentage of large vegetated patches	Access to community parks
Land productivity (measured by Vegetation Index as proxy)	Connectivity of vegetated patches	Access to large natural areas
	Quality of ecological corridor	

- *Basic natural service indicators*

Three indicators are used to measure basic natural services: air quality, water quality, and land productivity. Because it is difficult to obtain detailed soil information for all cities, the vegetation index, which is measured at the ecological level, is used as a proxy to represent land productivity as well.
Different countries use different systems to rate surface water quality. In the US, each state has varying standards that can be summarized into classes showing the appropriate use of water, such as fishable, swimmable, or impaired thus not recommended for any use. Other countries have similar standards of rating water quality. These different standards are normalized into ratings from 1 to 5 to represent water quality in different cities (See Table 3). If the city has two or more major rivers or water bodies nearby, the mean value is used. The air quality measurement comes from two sources. The first is the World Health Organization's ambient air pollution database that contains results of monitoring from almost 1600 cities. The second is the airnow.gov website using Air Quality Index (AQI) to show live and historical air quality data for cities. The AQI, which also provides a way to normalize different air quality standards across different countries, is therefore adopted in this study (Table 3).

- *Ecological indicators*

At the ecological level, the key focus is the flora and fauna and their self-sustainability. Four indicators could be generated with available remote sensing data. The first is the Normalized Difference Vegetation Index (NDVI), typically used to measure the abundance of vegetation based on Landsat satellite images. Best Landsat images taken in May were retrieved from the U.S. Geological Survey (USGS) website and analyzed for cities in the northern hemisphere while images taken in November are used for southern hemisphere cities. The temporal choice of images guarantees the amount of vegetation on the ground and cloudless condition to conduct NDVI analysis. Each city received a mean NDVI value within the study boundary to represent the overall vegetation quality.
The second indicator is the number and percentage of large vegetated natural patches. Large patches refer to vegetated land areas larger than 250 hectares because research suggests that such size could

host a variety of plant species and provide good habitat with enough buffer for wildlife (Barnes & Adams, 1999). Natural patches of such size are more self-sustaining and resilient than smaller patches (Forman 1995; Dramstad, Olson, and Forman, 1996).

The third indicator, connectivity, refers to functional connections among vegetated patches. When patches are close enough to each other, they can serve as "stepping stones" for dispersal of wildlife, becoming "connected" ecologically. The definition of a "functional connection" between patches depends on the application or process of interest. Patches that are connected regarding birds' dispersal might not be connected when considering the dispersal of small mammals. This study focuses solely on birds because they are prevalent and well-studied by scholars. Birds are also exemplary to strategies that encourage coexistence of humans and wildlife species (Jokimäki et al., 2011). The Connectivity index is defined by the percentage of functional connections between vegetated patches out of all the possible connections. Each pair of patches is either connected or not based on a user-specified distance (McGarigal & Marks, 1995). In this study, the threshold distance is set as 200 meters, balancing the threshold distance of 50 meters to 400 meters in urban areas identified by some bird dispersal studies (Harris & Reed, 2002; Hashimoto, 2008). The calculation is conducted in the FRAGSTATS program.

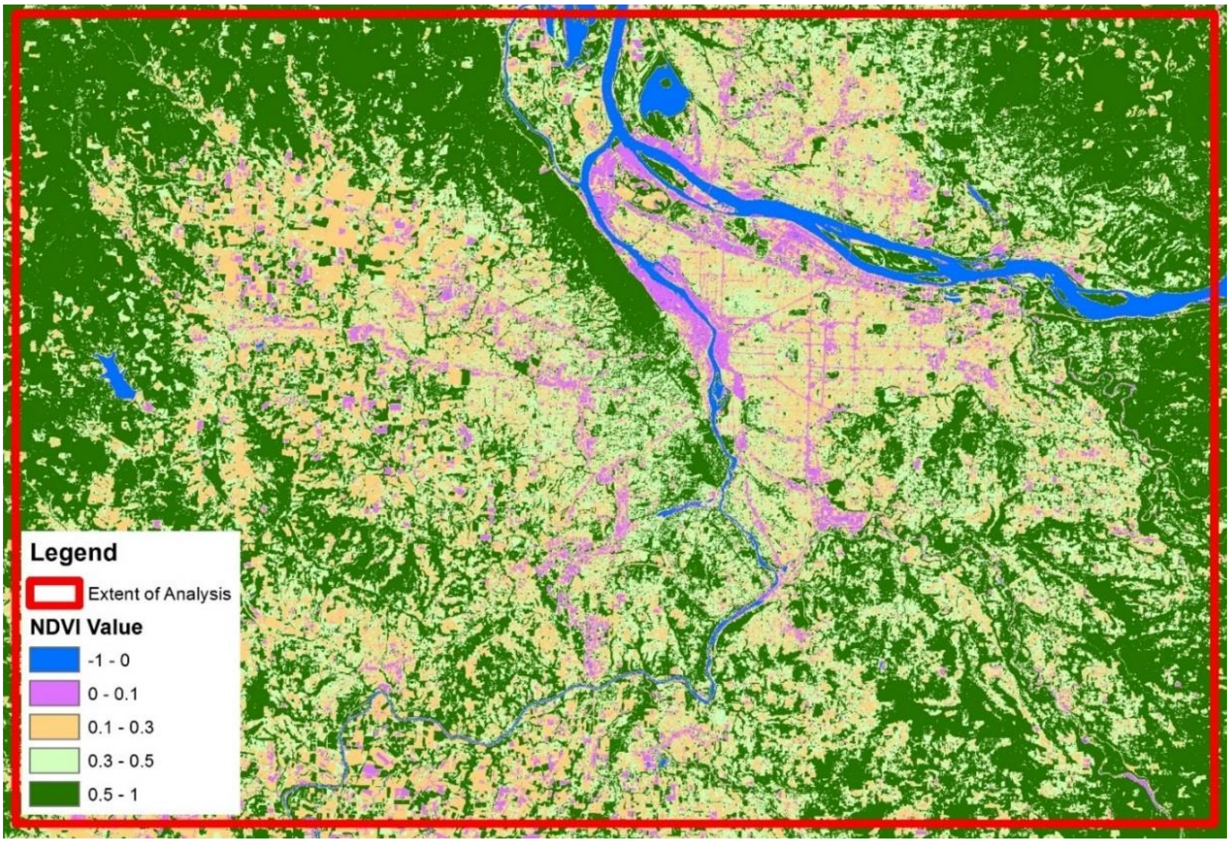

Figure 2: NDVI of Portland in May, dark green represents dense vegetation.

The last important indicator at this level is the condition of greenways that connect vegetated patches. Greenways are linear landscape elements that provide ecological, recreational, cultural, aesthetic, or other benefits (Ahern, 1995). Greenways allow the migration of wildlife species, encourage the flow of nutrients across regions, and provide recreational opportunities for humans to engage with nature. In this study, the mean NDVI value along an existing river corridor is used as the proxy to evaluate the health of greenways because riparian zones are often regarded as the most important greenways.

- *Human-nature interaction indicators*

Finally, the level of human-nature interaction is measured by the accessibility of urban parks or vegetated areas in different sizes. We classify parks and vegetated areas into three categories: regional parks are vegetated areas larger than 60 hectares with some important ecological functions and are reachable within a 20 kilometers radius. District parks are the vegetated areas between 10 and 60 hectares with a variety of amenities for different recreational uses. They should be reachable within 8 kilometers radius. Local small parks are between 0.2 and 10 hectares. They often serve as community parks that provide residents daily exposure to nature and should be within 2 kilometers distance from urban residents. We also weigh the population density when we assess proximity. The percentage of urban residents served by different levels of parks is thus calculated as an important indicator of human-nature interaction in the cities. If a city does not have available park data, the result from NDVI is used to identify potential parks and to classify them into the three classes based on the patch size.

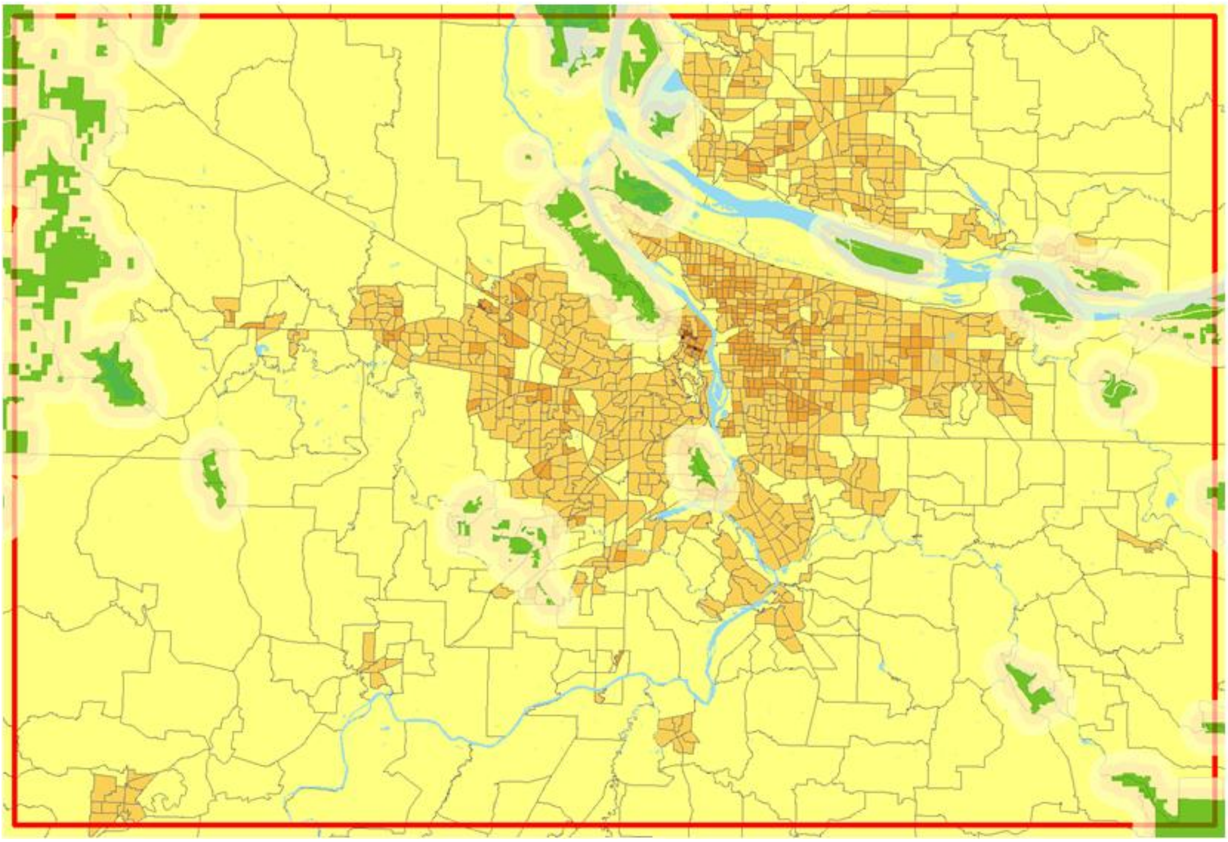

Figure 3: Accessibility to a large park by population density in Portland

2.3 Assessment

To conclude, all quantitative indicators are summarized into ratings from 1 to 5. The classes in the summary table are created based on possible ranges of indicators. The final Biophilic City Index is the total sum of all the summarized indicators.

As a city known for its greenness, Portland unsurprisingly scored mostly 5s and 4s in the indictors at the ecological and human-nature interaction levels. The city has abundantly vegetated areas that are well connected functionally. River corridors are also effective greenways that can support a variety of wildlife species. Urban residents can easily visit large regional parks and natural reserves that surround the city. To bring nature closer to the city, Portland could improve in two major areas as suggested by the Index. First, the water quality in the Willamette River has long limited its potential recreational use. Secondly, there is room to improve the service coverage of district and local parks, especially in the eastern part of the city. These issues revealed by the Biophilic City Index align with current city efforts. The Office of Environmental Services in Portland has recently completed a 20-year program to control combined sewer overflows. The water quality is expected to improve gradually to give urban residents more opportunities to enjoy the river. And in its recent park plan, the City of Portland has made a plan to acquire more land for future new parks. Such alignment with planning goals suggests that the indicators chosen are meaningful and effective.

3. DISCUSSION

The Biophilic City Index adds a new perspective to the existing collection of city indices. It continues the trend of valuing the quality of the living environment when assessing livability. Although the current Biophilic City Index is not entirely designed to compare cities directly, due to each city's unique natural setting, there are components, such as accessibility of natural areas that could be used for peer cities to compare and compete. This Index could help cities examine their current urban form and urban planning practices and find ways to improve the human-nature relationship, therefore making cities more biophilic.

This Biophilic City Index could also contribute to the current debate between New Urbanism and Landscape Urbanism. On one side, New Urbanism emphasizes proper density and critical mass to make a city more functional and efficient. On the other side, Landscape Urbanism and Ecological Urbanism emphasize the provision of ecological landscapes within the city. The notion of the Biophilic City also draws attention in this debate as it proposes to add more natural areas in cities. However, the Biophilic City Index might provide a new angle in this debate: there may be a way to achieve both a high-density urban environment and high-quality, easily accessible natural areas in cities through better spatial configuration as some indicators suggest. As our research on international cities unfolds, is it expected that international cases will shed new light on the debate.

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Table 3: Summary Table

Indicators	Categories	Rating	Portland
Water quality	Excellent - Pristine, provides habitats for different species	5	3
	Good - Clean and natural looking, swimmable	4	
	Fair - Natural looking, but not good for recreational use	3	
	Poor – Polluted	2	
	Very poor - Heavily polluted	1	
Air quality	Good	5	4
	Moderate	4	
	Unhealthy for sensitive groups	3	
	Unhealthy	2	
	Very unhealthy to hazardous	1	
Vegetation	NDVI 0.4-1	5	5
	NDVI 0.3-0.4	4	
	NDVI 0.2-0.3	3	
	NDVI 0.1-0.2	2	
	NDVI 0-0.1	1	
Percentage of large vegetated patches	>40%	5	5
	30-40%	4	
	20-30%	3	
	10-20%	2	
	< 10%	1	
Connectivity of vegetated patches	>20%	5	4
	15-20%	4	
	10-15%	3	
	5-10%	2	
	< 5%	1	
Quality of ecological corridor	NDVI 0.4-1	5	5
	NDVI 0.3-0.4	4	
	NDVI 0.2-0.3	3	
	NDVI 0.1-0.2	2	
	NDVI 0-0.1	1	
Access to regional parks	>80%	5	5
	60-80%	4	
	40-60%	3	
	20-40%	2	
	<20%	1	
Access to district parks	>80%	5	4
	60-80%	4	
	40-60%	3	
	20-40%	2	
	<20%	1	
Access to community parks	>80%	5	4
	60-80%	4	
	40-60%	3	
	20-40%	2	
	<20%	1	
TOTAL			37

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